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(71) Applicant
The Plessey Company
Limited
Vicarage Lane
Ilford
Essex
(72) Inventor
Robert Edward Poole
Geoffrey Howells
(74) Agents
H Ibbotson

(54) Metal detector

(57) This invention relates to a pulsed eddy current metal detector.

A transmitter coil 1 transmits a pulsed signal and a detector coil 3 detects a magnetic field produced by decaying eddy currents induced in conductive material in the region of the coil 3 by the pulsed signal. The presence of metal is indicated by sampling signals detected by the detector coil at least twice and at different times during the decay of the induced eddy currents e.g. by sample and hold circuits 4,5, the outputs of which are fed via amplifiers 8,9 of suitable gain to subtractor 10.

The invention is particularly useful for detecting metal object which would otherwise be masked by unwanted background signals caused by unwanted targets, for example wet ground, which signals are eliminated by circuit 10 and suitable setting of the gains of amplifiers 8,9. The apparatus may be used to sort coins.

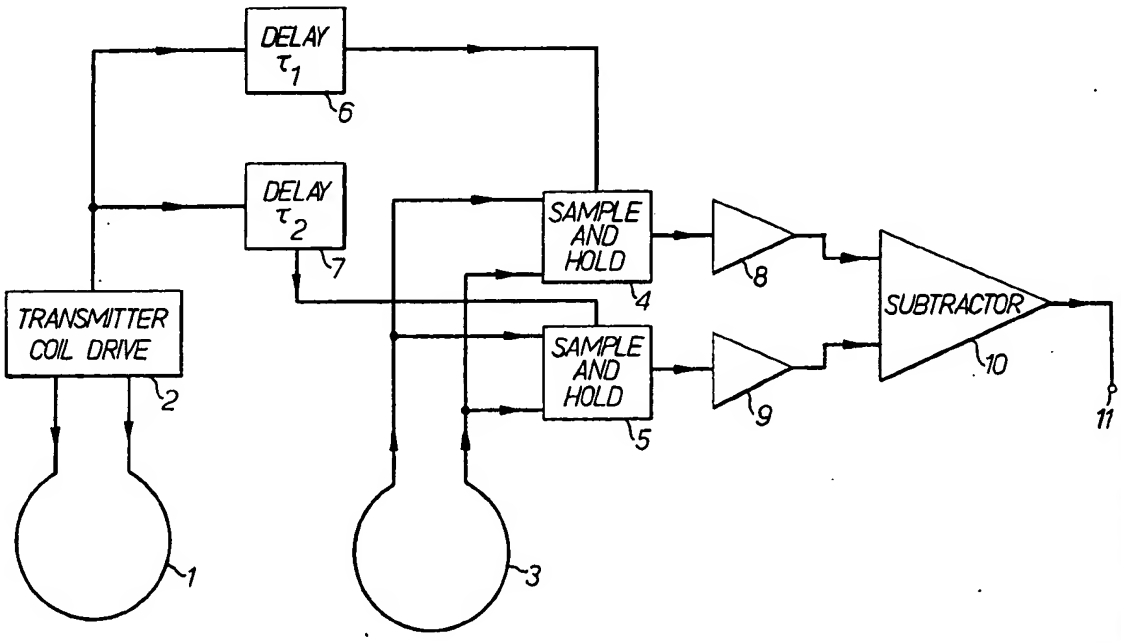

FIG. 1.

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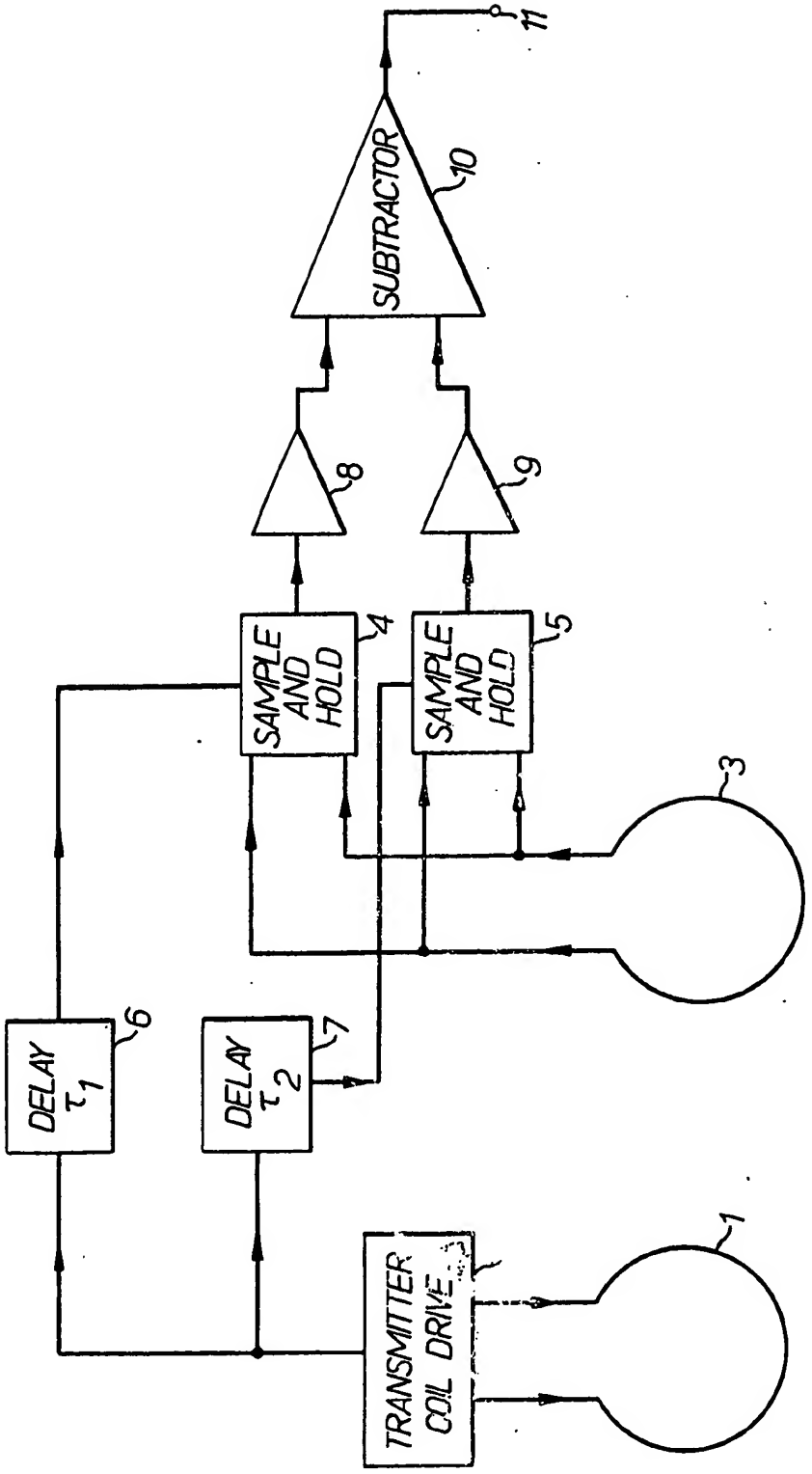
11
SUBTRACTOR
10
8
9
SAMPLE AND HOLD
4
SAMPLE AND HOLD
5
3
DELAY τ_1
6
DELAY τ_2
7
TRANSMITTER COIL DRIVE
1

FIG. 1.

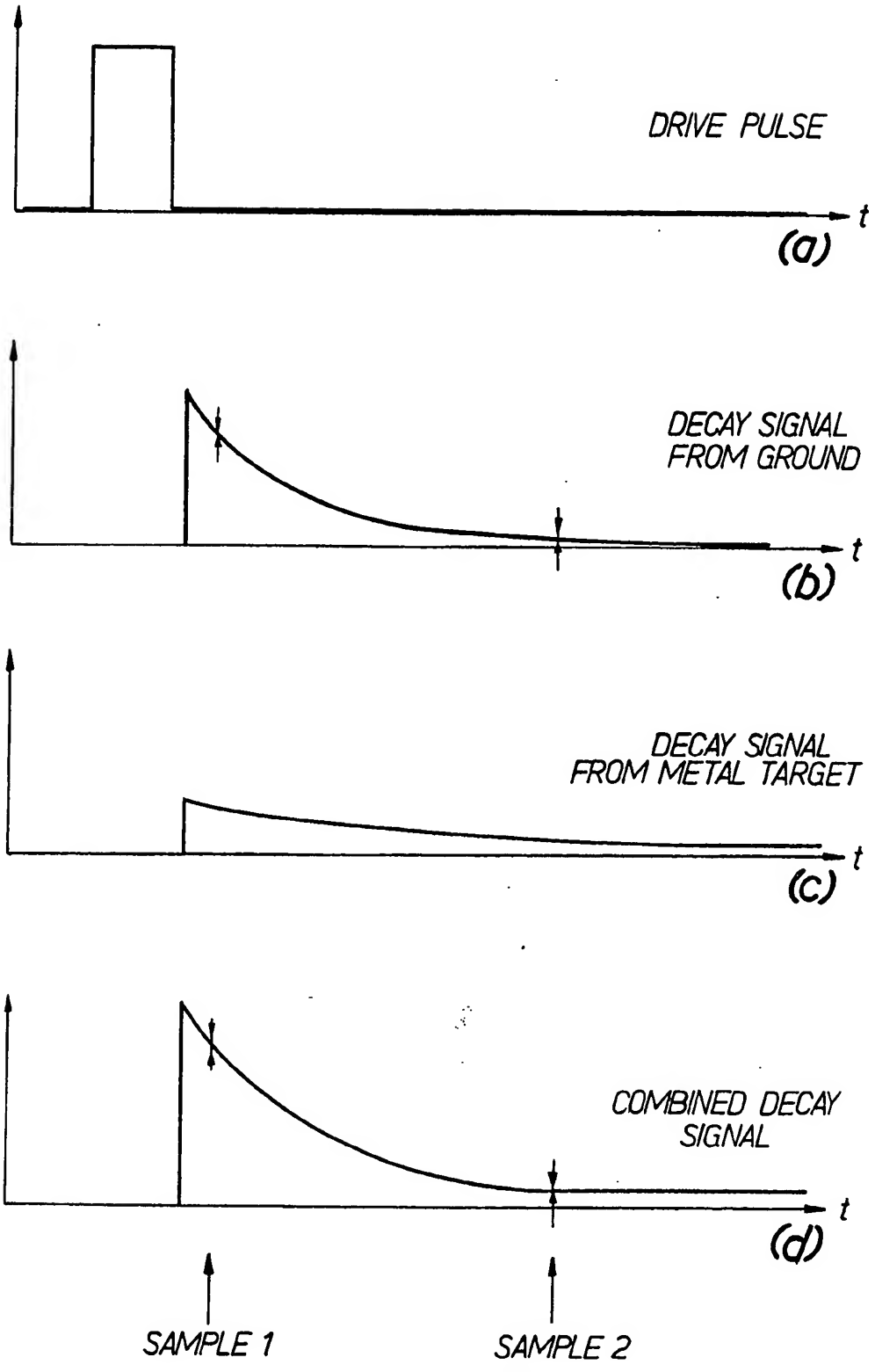
DRIVE PULSE
t
(a)
DECAY SIGNAL
FROM GROUND
t
(b)
DECAY SIGNAL
FROM METAL TARGET
t
(c)
COMBINED DECAY
SIGNAL
t
(d)
SAMPLE 1
SAMPLE 2

FIG.2.

SPECIFICATION

Metal detector

The invention relates to a metal detector and particularly to a detector of the pulsed eddy current type.

In a pulsed eddy current metal detector a pulse signal is transmitted and this signal induces an eddy current in any conductive material which receives the transmitted signal.

The induced eddy current decays approximately exponentially and the magnetic field caused by the decaying current is detected and sampled after the pulse signal has disappeared to indicate the presence of any conductive material.

A problem with all metal detectors is unwanted background signals caused by an unwanted target, for example the ground. All ground is to some extent conductive and wet ground particularly so. A pulsed eddy current detector will induce decaying eddy currents in the ground and the effects of these is to mask the presence of metal objects which it is desired to find the detector being unable to discriminate between the objects and unwanted targets.

This invention seeks to provide a pulsed eddy current detector in which the above problem is mitigated.

According to this invention there is provided a pulsed eddy current metal detector comprising means for transmitting a pulsed signal, a detector coil for detecting a magnetic field produced by decaying eddy currents induced in conductive material in the region of the coil by the pulsed signal, sampling means for sampling at least twice and at different times during decay of the eddy currents signals produced by the detector coil and processing means for receiving the samples produced by the sampling means and for providing an output signal indicative of the presence of a metal object.

The sampling means may comprise a pair of sample and hold circuits coupled to the detector coil each arranged to sample signals detected by the detector coil at a respective time during the decay of the eddy currents.

Each sample and hold circuit may be triggered by the means for transmitting a pulsed signal via a respective delay circuit.

The processing means may comprise amplifier means for amplifying the samples by respective amounts and a subtraction circuit for subtracting amplified samples from one another.

This invention will now be described further by way of example with reference to Figs. 1 and 2 of the drawings in which:

Figure 1 shows a metal detector in accordance with this invention; and

Figure 2 is an explanatory Figure showing transmitted and detected electrical signals in the arrangement of Fig. 1.

Referring to Fig. 1 the metal detector comprises a transmitter coil 1 which is connected to be energised by a transmitter coil drive circuit 2 which periodically supplies a pulse of current to the coil 1. Each current pulse is operative to cause a build-up of a magnetic field between the transmitter coil 1 and an area which is being surveyed for metal objects followed by a rapid collapse of this magnetic field.

The rapid decay of the magnetic field caused by the collapse of current in the transmitter coil 1 sets up eddy currents in any conductive material in the vicinity of this collapsing field and these eddy currents subsequently decay. The decay of the eddy currents is sensed in known manner by a detector coil 3 and detected signals are fed to a pair of sample and hold circuits 4 and 5. The sample and hold circuits 4 and 5 are operative to sample signals sensed by the detector coil 3 and are triggered to effect sampling by the transmitter coil drive circuit 2 via respective delay circuits 6 and 7. The delay circuits 6 and 7 respectively have delays τ_1 and τ_2 which ensure that the sample and hold circuits 4 and 5 sample signals sensed by the detector coil 3 at different points in time and after the cessation of the energising pulse applied to the transmitter coil 1, so that any direct effects produced in the detector coil 3 by the presence of the signal applied by the transmitter coil drive circuit 2 have disappeared and cause no damage to sensitive circuitry.

The sample and hold circuits 4 and 5 respectively provide output signals to amplifiers 8 and 9 which are operative to provide output signals which contain unwanted signals of substantially equal level to respective inputs of a subtractor circuit 10 which is operative to subtract signals fed to its two inputs and to provide output signals to an output terminal 11. The delay circuits 6 and 7 have delays τ_1 and τ_2 and if τ_2 is greater than τ_1 then in view of the decay signals sensed by the detector coil 3 the amplifier 9 will need to have a larger gain than that of amplifier 8 in order to provide output signals having unwanted signals of the same level as those from the amplifier 8.

Operation of the metal detector will now be described in conjunction with Fig. 2 in which it is assumed that the unwanted target is ground. At line (a) of Fig. 2 there is shown a drive pulse which is applied to the transmitter coil 1 by the transmitter coil drive circuit 2. This pulse on cessation will produce a rapidly collapsing magnetic flux which will induce eddy currents in both a wanted metal target and in the ground and these eddy currents will start to decay. Induced eddy currents in both the ground and the metal target will decay exponentially but in view of the differ-

ent nature of the ground and of the target the time constant of the decay will be different in each case.

The ground can be considered as being primarily resistive in nature and therefore eddy currents induced in the ground will decay fairly rapidly whilst a metal target is much more inductive than the ground and therefore eddy currents induced in a metal target will decay more slowly than those induced in the ground. Typical curves showing eddy current decay in the ground and in a metal target are shown respectively at lines (b) and (c) of Fig. 2. Decaying magnetic fields caused by the decaying signals will be sensed by the detector coil 3 which will effectively see a decaying signal which is a combination of the curves shown at (b) and (c) and is indicated at line (d) of Fig. 2.

The combined decaying signal sensed by the detector coil 3 is sampled at two points as indicated in Fig. 2, the first sample being taken after a delay τ_1 from cessation of the drive pulse and the second sample after a delay τ_2. Due to the faster decay of the eddy current signal from the ground the second sample contains a greater proportion of the target signal than the first sample so that by amplifying the second sample so that ground signal components have substantially the same level as in the first sample and subtracting the two in the subtractor 10 signals due to eddy currents in the ground cancel and a signal is provided at the terminal 11 indicative of the presence of a wanted target. This signal can then be used to activate any known type of alarm.

It is possible to reject targets with either a short time constant as in this example or with a long time constant by suitably adjusting the gains of the two amplifiers.

As can be seen this invention can be used to locate metal objects in the presence of strong interfering signals from unwanted objects for example the ground. Th invention is particularly useful for locating metal objects in wet ground and under the sea floor. The sea/sea floor interface gives a strong interfering signal which can be cancelled using the above described arrangement of taking a number of samples of decaying eddy currents and suitably processing to eliminate the unwanted signals. Although the invention has been described with reference to the location of metallic objects in ground it can be applied equally to distinguishing between different types of metallic objects and may be used for example to detect a small coin laying on a large slab of steel plate. The interfering signals caused by the steel plate being eliminated by the amplification and subtraction of at least two samples. Signals from any type of unwanted target may be cancelled. Modifications may be made to the described apparatus without departing from the scope of the invention. For example whilst the invention has been particularly described using separate transmitter and detector coils these coils can be combined into a single coil as known in the art if required. Although in Fig. 1 samples are suitably amplified so that unwanted signals in two samples have the same level and are then subtracted this is not essential and if desired other processing methods may be used to eliminate unwanted signals. For example two samples may be amplified by the same amount and a ratio of the two samples taken. This will once again remove any unwanted interfering signal to provide indications of only wanted targets. Although the invention has been described using only two samples it is of course possible to take any number of samples.

The invention is applicable to the sorting of metal objects i.e. coins. In this case two samples may be taken for each object and the relationship e.g. ratio between the samples compared with valves in a look-up table for each object. The look-up table may conveniently be in the form of a read only memory (R.O.M.).

CLAIMS

1. A pulsed eddy current metal detector comprising means for transmitting a pulsed signal; a detector coil for detecting a magnetic field produced by decaying eddy currents induced in conductive material in the region of the coil by the pulsed signal, sampling means for sampling at least twice and at different times during decay of the eddy currents, signals produced by the detector coil and processing means for receiving the samples produced by the sampling means and for providing an output signal indicative of the presence of a metal object.

2. A metal detector as claimed in claim 1 in which the sampling means comprises a pair of sample and hold circuits coupled to the detector coil each arranged to sample signals detected by the detector coil at a respective time during the decay of the eddy current.

3. A metal detector as claimed in claim 2 in which each sample and hold circuit is triggered by the means for transmitting a pulsed signal, via a respective delay circuit.

4. A metal detector as claimed in any one of claims 1 to 3 in which the processing means comprises amplifier means for amplifying the samples by respective amounts and a subtraction circuit for subtracting amplified samples from one another.

5. A pulsed eddy current metal detector substantially as herein described with reference to Figs. 1 and 2 of the drawings.

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